TIMING OF EARLY TERTIARY RIDGE SUBDUCTION IN SOUTHERN ALASKA

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ABSTRACT

We present a new compilation of 158 isotopic ages from Tertiary plutons that intrude the accretionary prism (Chugach–Prince William composite terrane) of southern Alaska. Two broad plutonic age groups are present: Paleocene to Eocene (the Sanak–Baranof plutonic belt), and Oligocene to Miocene. Plutons of the Sanak–Baranof belt are broadly coeval with magmatism along the axis of an Andean-type arc that lay farther inboard. A plot of age versus position along strike shows that near-trench magmatism progressed from about 66–63 Ma in the west to about 50 Ma in the east. We interpret the near-trench magmatism as the product of subduction of the Kula–Farallon ridge (or another unidentified spreading center) and suggest that the age progression tracks a migrating trench-ridge-trench triple junction along the continental margin.

INTRODUCTION

Subduction of the Kula–Farallon ridge beneath the North American continent is a fundamental feature of all marine-based global plate reconstructions for early Tertiary time (Byrne, 1979; Engebretson and others, 1985; Stock and Molnar, 1988; Lonsdale, 1988; Atwater, 1989). In all reconstructions, however, the position through time of the trench-ridge-trench triple junction between the Kula, Farallon, and North American plates, where ridge subduction occurred, has been hypothetical. Although none of the published reconstructions have placed the triple junction farther north than Vancouver Island, evidence does exist in southern Alaska that a spreading ridge—perhaps the Kula–Farallon, or perhaps another ridge—was subducted in early Tertiary time.

The near-trench position and geochemistry of plutons of the Sanak–Baranof belt of Hudson and others (1979) (fig.1) have led several previous workers to link this magmatic event to subduction of the Kula–Farallon ridge (Hill and others, 1981; Helwig and Emmet, 1981; Moore and others, 1983). In this paper, we discuss another aspect of Sanak–Baranof magmatism that supports the ridge-subduc-tion hypothesis: the age pattern of magmatism along the belt. Several previous workers have commented, without thorough documentation, on the spatial distribution of ages along the belt. Hudson and others (1979), Hudson (1983), and Barker and others (1992) have contended that there were two pulses: at about 60 Ma in the west (Sanak Island to Kodiak Island) and at about 50 Ma in the east (Prince William Sound to Baranof Island). Others have argued, also without much documentation, that these same ages show a progression from 65–60 Ma in the west to 50–45 Ma in the east (Hill and others, 1981; Helwig and Emmet, 1981; Moore and others, 1983). An age progression of near-trench magmatism would be most readily interpreted in terms of ridge subduction, whereas a bimodal age pattern might have a number of possible causes.

Accordingly, in this paper we present a compilation of isotopic ages from the Sanak–Baranof belt (table 1) and discuss some tectonic implications of these ages. The available data now span the entire Sanak–Baranof belt without major gaps; new $^{40}Ar/^{39}Ar$ and U/Pb determinations fill what had been a crucial gap between Kodiak Island and Prince William Sound, where an age jump would occur if the age distribution were bimodal. The available data show that Sanak–Baranof magmatism progressed generally from west to east, in support of the ridge subduction model. This conclusion has implications for plate reconstructions, terrane displacement, orocline formation, gold mineralization, and deformation of the accretionary wedge.

REGIONAL GEOLOGY

Plutons of the Sanak–Baranof belt intrude a complexly deformed Mesozoic and Cenozoic accretionary prism—the Chugach–Prince William composite terrane (the term "composite" is omitted below for brevity) (fig.1)—along the seaward margin of the Peninsular–Wrangellia–Alexander composite terrane. Plafker and others (in press) provide a thorough review of the regional geology. The inboard part of the prism is a melange of relatively competent blocks and fault slices of basalt, chert, and graywacke, in an argillite matrix (Early Cretaceous Uyak Complex, Triassic to mid-Cretaceous McHugh Complex, and Late

Jurassic to mid-Cretaceous Kelp Bay Group: Connelly, 1978; Bradley and Kusky, 1992; Decker, 1980). Farther outboard is a belt of Upper Cretaceous flysch, assigned to the Shumagin Formation, Kodiak Formation, Valdez Group, and Sitka Graywacke (part) (Moore, 1973; Nilsen and Moore, 1979; Nilsen and Zuffa, 1982; Decker, 1980). Still farther outboard lie belts of flysch assigned to the Ghost Rocks Formation and Orca Group (Moore and others, 1983; Moore and Allwardt, 1980; Helwig and Emmet, 1981). The Ghost Rocks Formation and Orca Group contain mafic and, in the latter case, ultramafic rocks that will be mentioned below as one line of evidence for ridge subduction. Penetrative deformation in the accretionary prism (thrust imbrication, folding, melange formation) and regional metamorphism (typically prehnite-pumpelleyite to greenschist facies) occurred during and shortly after subduction-accretion during the Cretaceous and early Tertiary. Near-trench plutons of the Sanak–Baranof belt were emplaced into the accretionary prism after this deformation. Another tract of accreted deep-sea turbidites (Eocene Sitkalidak Formation and the outboard part of the Orca Group; Moore and Allwardt, 1980; Helwig and Emmet, 1981) lies outboard of the Sanak–Baranof belt; these younger turbidites are not cut by the plutons, and hence are probably younger.

Paleocene to Eocene plutons of the Sanak–Baranof belt crop out discontinuously along the entire 2,200 km length of the Chugach–Prince William terrane. The plutons are mainly granodiorite, granite, and tonalite (Hudson, 1983). Some of the plutons are elongate parallel to structural grain of the accretionary prism; others are transverse. Some are enormous—the Kodiak batholith, for example, is

more than 100 km long and up to 10 km wide. In the eastern Chugach Mountains, magmatism was accompanied by high-grade regional metamorphism and anatectic melting of flysch (Hudson and Plafker, 1982; Sisson and others, 1989). Paleocene to Eocene intermediate to silicic dikes are plentiful in some regions, such as the Kenai Peninsula (Winkler, 1992; Bradley and Kusky, 1992). Oligocene to early Miocene plutons intruded the Chugach–Prince William terrane in southeastern Alaska and Prince William Sound; post-Eocene plutons have not been recognized from the Kenai Peninsula to Sanak Island.

ISOTOPIC AGES FROM THE SANAK–BARANOF BELT

Isotopic ages from intrusive rocks in the Chugach–Prince William terrane are compiled in table 1. Most of these data are contained in recent compilations of much broader scope by Wilson and others (1991) for Alaska and by Dodds and Campbell (1988) for the Yukon and British Columbia. Alaskan ages from pre-1977 sources were recalculated by Wilson and others (1991) using decay constants recommended by Steiger and Jäger (1977). A few intrusions from the Peninsular–Wrangellia–Alexander composite terrane (Winkler, 1992; Loney and others, 1975) probably could be included in the Sanak–Baranof belt, but because a near-trench position during magmatism cannot be as readily demonstrated as for the Chugach–Prince William terrane, we have not tabulated these ages; in any case, their inclusion would not change our conclu-
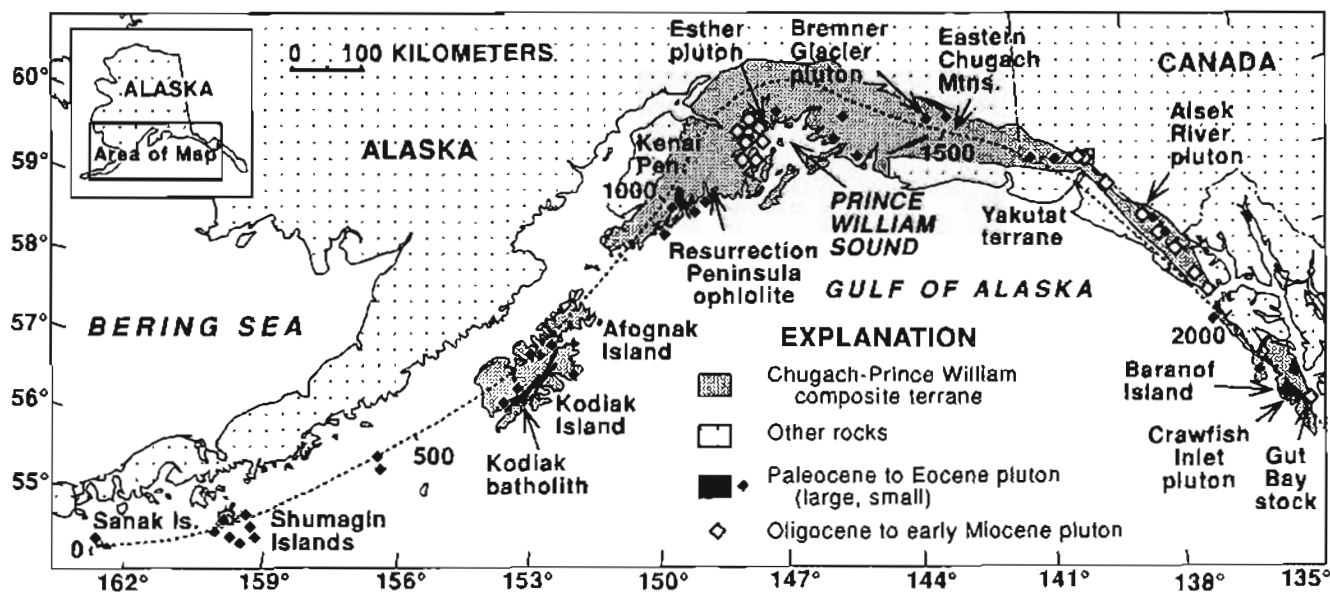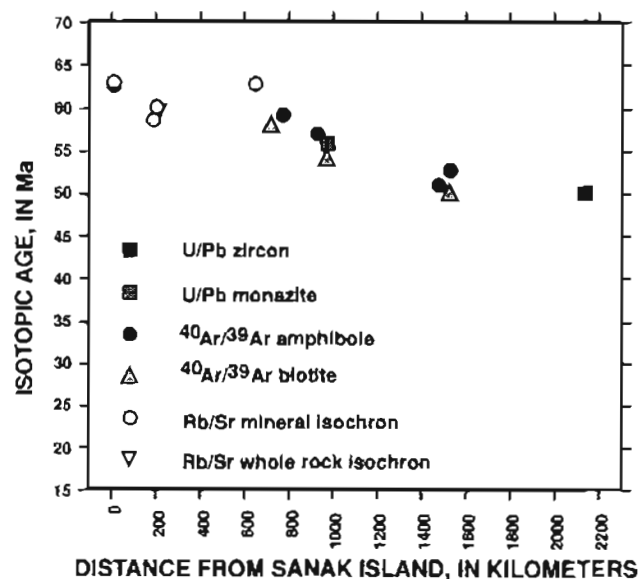

Figure 1. Generalized geologic map of southern Alaska showing plutons of Sanak–Baranof plutonic belt, Chugach–Prince William composite terrane, and localities mentioned in text. Numbers along dashed reference line show distance in kilometers from southern tip of Sanak Island to Baranof Island.

sions. We also have excluded data from the Yakutat terrane in southeastern Alaska (fig. 1), which is interpreted as a former southerly continuation of the Chugach–Prince William terrane that was translated about 600 km north with respect to the rest of the terrane during the Cenozoic (Plafker, 1987). Although the Sanak–Baranof belt as defined by Hudson and others (1979) is Paleocene to Eocene in age, table 1 includes ages ranging from Late Cretaceous to Miocene, as discussed below.

Of the 158 ages listed in table 1, 30 were rejected for inclusion in figure 2 for failure to meet the lenient selection criteria identified in the "Notes" column of table 1. Ages with errors greater than 10 percent were judged to be unacceptable. Ages from plutons with multiple determinations were either rejected if judged to be discordant, or accepted for inclusion in figure 2 if judged to be concordant or problematic. A pair of ages was considered to be discordant if the difference in ages was greater than 6 million years (m.y.), or greater than the sum of errors, using the more lenient standard in each case. The younger of a discordant pair was rejected. For three or more ages from the same pluton, discordance was determined starting from the oldest, by comparing one age with the next younger age only. For example, for a pluton with ages of 50, 46, and 43 Ma (±2 in all cases), all three ages would be accepted as concordant for present purposes. If, however, the only available ages were 50 and 43 Ma, the 43-Ma age would

be rejected as discordant. There are a few problematic plutons in the eastern Chugach and St. Elias Mountains from which the oldest age, determined by conventional K/Ar on amphibole, is the questionable one. Problems with these amphibole ages, which define field 5 in figure 2B, are discussed below. For these plutons, all the ages—even those that we suspect are spurious—were accepted.

Two plots of isotopic age versus position along strike (excluding rejected data) are shown in figure 2. U/Pb, ^{40}Ar/^{39}Ar, and Rb/Sr data (fig. 2A) show a *general* west-to-east age progression from 66–63 Ma in the west to 50 Ma in the east. Despite greater scatter, the same trend is also evident from conventional K/Ar data (field 1 in fig. 2B), especially west of Prince William Sound. From Prince William Sound eastward, K/Ar ages cluster in five fields (fields 1–5). Field 1 corresponds to the Sanak–Baranof belt as defined by Hudson and others (1979); fields 2–5 are discussed at greater length below. The timing of magmatism at the eastern end of the Sanak–Baranof belt is well constrained by a U/Pb zircon age of 50.1 ± 0.1 Ma from the Crawfish Inlet pluton (Brew and others, 1991). The onset of magmatism at the opposite end of the belt is less tightly dated, because only conventional K/Ar and Rb/Sr isochron ages are available. The oldest age from the Sanak pluton at the extreme end of the belt is an Rb/Sr mineral isochron of 63.1 ± 1.2 Ma (Hill and others, 1981); the oldest age from the Shumagin pluton, about 200

ISOTOPIC AGE, IN Ma

- ■ U/Pb zircon
- ▨ U/Pb monazite
- ● ^{40}Ar/^{39}Ar amphibole
- △ ^{40}Ar/^{39}Ar biotite
- ○ Rb/Sr mineral isochron
- ▽ Rb/Sr whole rock isochron

DISTANCE FROM SANAK ISLAND, IN KILOMETERS

A

ISOTOPIC AGE, IN Ma

- □ K/Ar amphibole
- ■ K/Ar muscovite
- ▨ K/Ar biotite/phlogopite
- △ K/Ar whole rock

DISTANCE FROM SANAK ISLAND, IN KILOMETERS

B

Figure 2. Plots of isotopic age versus distance along strike around Sanak–Baranof plutonic belt. Data are listed in table 1 and selection criteria for including in these plots are discussed in text. A, U/Pb, ^{40}Ar/^{39}Ar, and Rb/Sr data. West-to-east age progression is consistent with triple junction migration. B, Conventional K/Ar data, showing same age progression (field 1) amidst scatter from a number of sources. Field 2, Oligocene
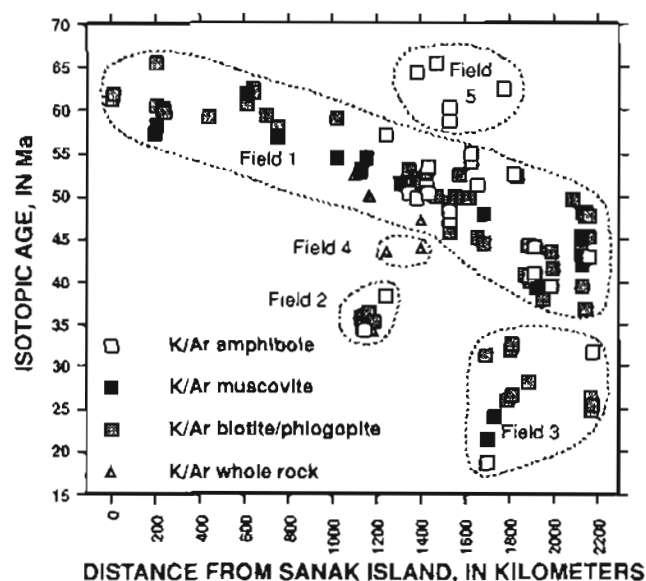
plutonic suite in Prince William Sound. Field 3, Oligocene to early Miocene plutonic suite in southeastern Alaska. Field 4, K/Ar whole-rock ages of dubious quality, probably subject to partial argon loss rather than a separate intrusive event. Field 5, Anomalously old hornblende ages from eastern Chugach and St. Elias Mountains, at least partly resulting from inherited argon.

km from the end of the belt, is a K/Ar muscovite age of 65.6 ± 3.3 Ma (Burk, 1965). Lacking better data, we have picked an age in the range 66–63 Ma for the onset of magmatism at the western end of the belt.

We attribute two of the other fields in figure 2B to younger magmatic events. Field 2 corresponds to a suite of Oligocene plutons in Prince William Sound. In contrast to the Paleocene to Eocene tonalite to granite plutons of the Sanak–Baranof belt, the Oligocene plutons of Prince William Sound typically are composite bodies of gabbro and granite (Nelson and others, 1985; Tysdal and Case, 1979). A new, unpublished $^{40}Ar/^{39}Ar$ biotite age of 36.1±0.1 Ma from the Esther pluton (L. Snee, written commun., 1993) suggests that the Oligocene conventional K/Ar ages from Prince William Sound are probably only a few million years younger than the age of intrusion. Field 3 includes K/Ar ages from seven plutons in southeastern Alaska. These plutons (for example, the Gut Bay stock and Alsek River pluton) have yielded Oligocene to early Miocene ages *only*; they record a magmatic event that is significantly younger than the Sanak–Baranof belt. Some other plutons in southeastern Alaska (for example, the Baranof Lake pluton) have yielded ages ranging from Eocene to Oligocene and even Miocene; we attribute these younger ages to cooling and (or) resetting rather than intrusion.

We attribute the remaining two fields in figure 2B to partial argon loss in one case and to inherited argon in the other. Field 4 in figure 2B includes two conventional K/Ar whole-rock ages of dubious quality. The ages are from dikes for which mineral ages were not obtained. Because none of the more reliable methods have yielded comparable ages in this region, the whole-rock ages probably record partial argon loss rather than a separate intrusive event. Field 5 is a group of amphibole ages from plutons in the eastern Chugach Mountains that fall above field 1. In a detailed case study, Onstott and others (1989) showed that amphiboles from two of these plutons had been contaminated by inherited argon. Actinolite/cummingtonite from the Bremner Glacier pluton yielded a conventional K/Ar age of 64.1 ± 7.0 Ma (George Plafker, cited in Onstott and others, 1989), in close agreement with a $^{40}Ar/^{39}Ar$ integrated (total gas) age of 66.4 ± 4.3 Ma, but far older than a corresponding $^{40}Ar/^{39}Ar$ plateau age of 54.0 ± 1.1 Ma. A slightly more reliable age of 51.2 ±4.3 Ma (table 1) was determined from the intercept on a plot of $^{36}Ar/^{40}Ar$ versus $^{39}Ar/^{40}Ar$; this correction uses the calculated initial argon isotopic composition rather than an assumed atmospheric composition (Onstott and others, 1989). In general, the K/Ar data show a great deal of scatter. In more than a third of the samples in table 1 from which two or more minerals have been dated by the conventional K/Ar method, the expected age progression hornblende > muscovite > biotite (a function of progressively lower blocking temperatures; McDougall and Harrison, 1988) does not apply.

DISCUSSION

GEOLOGIC EFFECTS OF RIDGE SUBDUCTION

The term "ridge subduction" describes the subduction of a divergent plate boundary beneath a convergent plate boundary at a trench-ridge-trench or trench-ridge-transform triple junction. The term is restricted to subduction of an oceanic spreading center, regardless of the presence or absence of a morphologic ridge, and is not to be confused with "aseismic ridge subduction," which applies to the subduction of seamounts. As discussed by Dickinson and Snyder (1979) and Thorkelson and Taylor (1989), a spreading center ceases to exist upon subduction. In its place, an ever-widening "slab window" opens down-dip of the triple junction. This window is an anomalously hot interface between the base of the overriding plate and asthenosphere that upwells from beneath the two subducted, but still diverging plates. Present understanding of the geologic effects of ridge subduction is derived from theoretical studies (Delong and Fox, 1977) as well as modern and ancient examples. There are two modern examples of "pure" ridge subduction (where the triple junction is of the trench-ridge-trench type): in the Chile trench (Forsythe and Nelson, 1985; Forsythe and others, 1986; Cande and Leslie, 1986; Scientific Party, 1992) and in the Solomon trench (Taylor and Exon, 1987; Perfit and others, 1987; Johnson and others, 1987). In addition, there are three examples of active "partial" ridge subduction along the west coast of North America, where the triple junctions are of the trench-ridge-transform type. Other Neogene ridge-subduction events have been identified in the Antarctic Peninsula (Barker, 1982) and in the Philippine Sea (Hibbard and Karig, 1990). The most striking geologic effect of ridge subduction is near-trench magmatism in a setting where low heat flow is the rule (Marshak and Karig, 1977).

INTERPRETATION OF SANAK–BARANOF MAGMATISM AS THE PRODUCT OF RIDGE SUBDUCTION

Although a number of possible explanations have been advanced, most present workers believe that Sanak–Baranof magmatism was the product of ridge subduction (Marshak and Karig, 1977; Hill and others, 1981; Helwig and Emmet, 1981; Moore and others, 1983; Plafker and others, 1989; Sisson and others, 1989; Bradley and Kusky, 1992; Barker and others, 1992; Bol and others, 1992; Winkler, 1992). Five independent lines of evidence that support this interpretation are summarized below.

(1) *Near-trench position of plutons.*—Plutons of the Sanak–Baranof belt intruded recently deformed deep-sea turbidites (Shumagin, Kodiak, and Ghost Rocks Formations, Valdez Group, inboard part of the Orca Group, and

Sitka Graywacke) in an accretionary prism (Marshak and Karig, 1977). During the same time interval, a more landward belt of plutons was also emplaced along what has been interpreted as an Andean-type magmatic arc (Armstrong, 1988; Plafker and others, in press). Sanak–Baranof plutonism in southeastern Alaska was coeval with a major magmatic pulse in the Coast Plutonic Complex (of Douglas and others, 1970), a huge coast-parallel batholith 100–150 km to the east (Brew and Morrell, 1983; Armstrong, 1988). Similarly, from Prince William Sound to Kodiak Island, Sanak–Baranof magmatism was at least partly coeval with magmatism along the 74- to 55-Ma Alaska–Aleutian Range batholith (Reed and Lanphere, 1973; Wallace and Engebretson, 1984), which parallels the Sanak–Baranof belt but lies 200–300 km inboard of it.

(2) *Geochemistry of near-trench plutonic rocks.*— Petrogenetic modeling of Paleocene granitoids on Kodiak Island suggests interaction between a parent magma similar to mid-ocean ridge basalt (MORB-like) and anatectically melted flysch at the base of the accretionary prism (Hill and others, 1981). Barker and others (1992) invoked heat from a subducted spreading center to melt the base of accretionary prism as an explanation for the geochemistry and isotopic composition of Eocene granitoids in eastern Prince William Sound.

(3) *Obducted ophiolites in the accretionary prism.*—In the Resurrection Peninsula ophiolite (57 Ma)(Nelson and others, 1989), pillow lavas at the top of an ophiolite sequence are interbedded with flysch, suggesting proximity of a spreading center to a sediment source along the continental margin (Bol and others, 1992). The agreement between the ages of ophiolite genesis and near-trench magmatism in nearby, previously accreted rocks of the Valdez Group suggests that while the ophiolite was being generated, a slab window (the subducted part of the spreading center) heated the base of the adjacent accretionary prism. Interbedded mafic volcanic rocks and turbidites in the Ghost Rocks Formation have also been interpreted as having formed at a ridge-trench-trench triple junction (Moore and others, 1983). These volcanic rocks have geochemical signatures that suggest mixing between a MORB-like magma and melted flysch (Moore and others, 1983).

(4) *High-grade metamorphism in parts of the accretionary prism.*—Although accretionary prisms are typically subject to relatively low temperature-high pressure metamorphism, parts of the Chugach–Prince William terrane experienced the opposite—high temperature-low pressure metamorphism (Hudson and Plafker, 1982). In the eastern Chugach Mountains, peak metamorphism, at about 675°C and about 3 kilobars, occurred at 58–56 Ma and was followed by rapid cooling to about 350°C by 50 Ma (Sisson and others, 1989). On Baranof Island, conditions of 790°C at 4.4 kilobars (garnet-cordierite zone) were reached during the Eocene in a broad tract of regional contact metamorphism (Loney and Brew, 1987).

(5) *Age progression of near-trench magmatism.*— Ridge subduction is the one mechanism for near-trench magmatism that is compatible with the age progression documented in figure 2B. Any effects of ridge subduction should generally be diachronous along the strike of a subduction zone, except in the two special cases where the subducted ridge is either exactly parallel or exactly perpendicular to the subduction zone (McKenzie and Morgan, 1969). Conversely, the age progression is inconsistent with other models for Sanak–Baranof belt magmatism. Hudson and others (1979) invoked spontaneous anatectic melting of recently accreted sediments; this, however, would require the diachronous accretion of a thick wedge of flysch along the whole 2,200-km-long belt shortly before magmatism commenced, for which there is no evidence. Even ignoring geochemical evidence against an arc environment (for example, Barker and others, 1992), the suggestion by Kienle and Turner (1976) that the western segment of the belt is a magmatic arc fails to account for the migration of a short-lived magmatic pulse 2,200 km along the continental margin. Another possible cause of near-trench magmatism is overriding a seafloor hot spot. In general, however, this would cause magmatism in only one place in the accretionary prism, not along its entire length. Only in the unlikely case where the trend of the subduction zone was parallel to the relative motion of the overriding plate in a hot-spot reference frame would near-trench magmatism be diachronous along strike. Finally, localized transtension along a transform margin might also explain a magmatic pulse close to a former trench, but this model cannot account for the observed age progression.

IMPLICATIONS FOR PLATE RECONSTRUCTIONS

The west-to-east age progression of near-trench magmatism suggests the migration of a triple junction (Helwig and Emmet, 1981; Moore and others, 1983) about 2,200 km along strike in about 13–16 m.y., at an average rate of about 140–170 km/m.y. It seems more likely that the triple junction was of the trench-ridge-trench type than a trench-ridge-transform type (McKenzie and Morgan, 1969), because accretion of the Valdez Group, Kodiak Formation, and Shumagin Formation immediately preceded near-trench magmatism, and accretion of the Sitkalidak Formation and outer part of the Orca Group immediately followed near-trench magmatism. Both accretionary episodes have been attributed to subduction, rather than to transform tectonics (Plafker and others, 1989; Moore and Allwardt, 1980).

Although most of the proponents of ridge subduction cited above have linked Sanak–Baranof magmatism to the Kula–Farallon ridge, the identity of the subducted ridge is debatable. As the triple junction migrated past a given point on the overriding accretionary prism, subduction of a

more easterly oceanic plate must have been succeeded by subduction of a more westerly oceanic plate (fig. 3). This statement is deliberately vague because it is unclear whether the Kula–Farallon ridge or a "West Kula–East Kula" ridge was subducted. The one ridge that *can* be eliminated is the Kula–Pacific (compare Delong and others, 1978), because recently discovered magnetic anomalies indicate that it ceased to spread at about 40–41 Ma, when it was thousands of kilometers offshore in the Pacific, far from the North American or Alaskan margin where it could have been subducted (Lonsdale, 1988; Lonsdale's age picks have been modified according to the new magnetic time scale of Cande and Kent, 1992). Simple plate circuitry among the North American, Pacific, Kula, and Farallon plates cannot further resolve the identity of the subducted ridge that we believe caused Sanak–Baranof magmatism, because so much ocean floor has been subducted since the early Tertiary (Atwater, 1989). Various reconstructions do agree, however, on the approxi-

mate offshore position of the Kula–Farallon–Pacific ridge-ridge-ridge triple junction at about 56 Ma (Engebretson and others, 1985; Stock and Molnar, 1988; Lonsdale, 1988; Atwater, 1989; Bol and others, 1992). These workers have inferred that the Kula–Farallon ridge trended from this triple junction toward the present coastal position of Vancouver Island. However, it might have been offset to the north or south by transforms (Bol and others, 1992)(fig. 3). Another possibility is that the Kula–Farallon ridge split into another ridge separating what could be called the "West Kula" and "East Kula" plates. Unfortunately, two postulated but poorly resolved onshore events complicate interpretations even further: (1) northward displacement of the Chugach–Prince William terrane by $13\pm9°$, during the interval from about 57 to about 45 Ma (Coe and others, 1985; Bol and others, 1992) and (2) formation of the southern Alaska orocline by $44\pm11°$ counterclockwise rotation of southwestern Alaska some time between about 65 and about 35 Ma (Coe and others, 1989). If both events have been correctly interpreted from the paleomagnetic record, all of the Sanak–Baranof belt was displaced northward relative to stable North America, and the part west of Prince William Sound was oroclinally rotated, possibly during emplacement of the Sanak–Baranof plutons.

Although a general west-to-east age progression is evident from figure 2, the available data do not allow resolution of a number of tectonically important details. The data do not even allow identification of the major plate

$\Leftarrow$
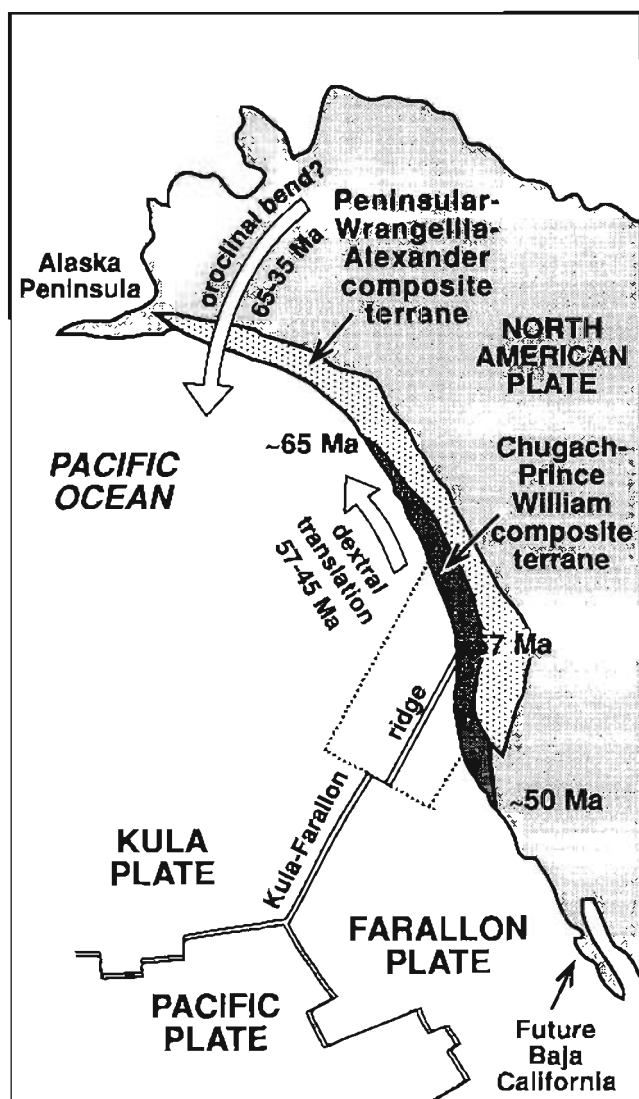
Figure 3. Early Tertiary plate reconstruction of northern Pacific, adapted from Bol and others (1992) and Engebretson and others (1985). Oroclinal bend has been straightened and Chugach–Prince William terrane has been restored to a more southerly position, following Bol and others (1992). Solid ridge-transform system shows inferred Kula–Farallon ridge configuration and position of triple junction at 57 Ma based on paleomagnetism (Bol and others, 1992). Relative positions of Kula–Farallon–North American triple junction at about 65 and about 50 Ma, based on the present study, are shown by numbers at either end of the Chugach–Prince William composite terrane in its restored position. Dashed ridge-transform systems are only two of an infinite number of possible alternative left-stepping and right-stepping ridge geometries. Two alternatives shown would suggest more northerly or more southerly positions of Kula–Farallon–North American triple junction, respectively. Small transform offset could have caused major shift in position of triple junction. Formation of orocline may not have spanned entire 65- to 35-Ma age range permitted by paleomagnetic data. Complete lack of data on seafloor-spreading history of northern part of area shown as Kula plate allows for possibility that Kula plate was, in fact, two plates—"East Kula" and "West Kula"—separated by yet another spreading ridge that has been entirely subducted.

reorganizations at about 54–52 Ma or 41–40 Ma seen in magnetic anomalies from the Pacific plate (these are the 56- and 42-Ma events of Engebretson and others, 1985, recalibrated to the new magnetic anomaly time scale of Cande and Kent, 1992). If Sanak–Baranof magmatism occurred at a migrating trench-ridge-trench triple junction, the presence of left-stepping or right-stepping tranforms along the subducting ridge would be expected to affect the position of the triple junction through time, in a manner not unlike that described by Atwater (1989) for the Pacific–Farallon–North American triple junction in California. Depending on the relative ages and (or) magnitudes of oroclinal bending, northward strike-slip of the Chugach terrane, and ridge subduction, interaction between these events could yield a multitude of possible age patterns on a plot like figure 2. Indeed, with 10–20 new, high-precision U/Pb and $^{40}Ar/^{39}Ar$ determinations from the Sanak–Baranof belt, such a plot might place some new, quantitative constraints on the early Tertiary tectonic evolution. The available data, however, only support qualitative conclusions. The claim by Hudson and others (1979) and some later workers that the Sanak–Baranof belt is divided by age into a westerly ~60-Ma half and an easterly ~50-Ma half definitely is not substantiated by figure 2. At most, figure 2 could be interpreted to show that magmatism was virtually coeval from Sanak to Kodiak Island, and progressively younger from there eastward (F. Wilson, written commun., 1993).

At least in southeastern Alaska, marine-based plate reconstructions imply that a transform margin existed after about 41–40 Ma (revised from 42 Ma using the new time scale of Cande and Kent, 1992) (Hyndman and Hamilton, 1990). Oligocene to Miocene plutonism in southeastern Alaska (field 3 in fig. 2B) is presumably somehow related to transform-margin tectonics along a Pacific–North American plate boundary. The cause of Oligocene plutonism in Prince William Sound (field 2 in fig. 2B) has not been investigated.

SHALLOW-LEVEL EFFECTS OF RIDGE SUBDUCTION IN THE ACCRETIONARY PRISM

Several recent models have treated accretionary prisms as wedges of material with an equilibrium "critical taper," much like a wedge of snow built up in front of a snowplow (for example, Davis and others, 1983; Platt, 1986). Subduction of a ridge at a migrating triple junction might be expected to have several disruptive effects on a critically tapered wedge. First, migration of a trench-ridge-trench triple junction past a given point would be accompanied by subduction of progressively more bouyant, topographically higher lithosphere, then less bouyant, topographically lower lithosphere. In addition, intrusion of large magma bodies into the prism would severely perturb

the stress field, because fluids cannot transmit shear stress. Finally, a change in rate and convergence direction would have to occur as the triple junction moved past a given place. Thus, passage of a triple junction would change the sense of obliquity of subduction, which in turn would change the sense and (or) rate of displacement of motion along trench-parallel faults in the forearc (Dewey, 1980).

Recent findings suggest that near-trench magmatism was coeval with regional-scale brittle deformation of the accretionary prism in the western part of the Sanak–Baranof belt (fig. 4), much as it was coeval with ductile deformation and metamorphism at deeper levels in the eastern Chugach Mountains (Sisson and others, 1989). In the southern Kenai Peninsula, dike trends indicate north-south extension, at about 45° to regional strike; one such dike yielded a $^{40}Ar/^{39}Ar$ hornblende age of 57 Ma (Bradley and Kusky, 1992). Mutual cross-cutting relations reveal that these dikes are coeval with a set of conjugate strike-slip cross-faults that caused orogen-parallel extension (Bradley and Kusky, 1992). Kinematic analysis of correlative faults from the northern Kenai Peninsula also indicates orogen-parallel extension (Bradley and Kusky, 1990); curved slickenlines on these faults indicate that stress orientations changed markedly during faulting, probably as a consequence of uplift. The occurrence of similar fault sets on Afognak and Kodiak Islands (Sample and Moore, 1987; Byrne, 1984) suggests that at least the western limb of the orocline underwent extension subparallel to structural grain. Hibbard and Karig (1990) described remarkably similar late faults and dikes in Japan where a spreading center was subducted during the Miocene.

Epigenetic gold-bearing quartz veins are widespread throughout the Chugach terrane, from Kodiak to Baranof Island. Isotopic ages from three sites in the Kenai Peninsula indicate that gold mineralization was coeval with magmatism in this part of the Sanak–Baranof belt. Like the magmatism, the gold mineralization must have occurred in a near-trench setting (fig. 4). Sericite from a gold-quartz vein from the Beauty Bay Mine yielded a $^{40}Ar/^{39}Ar$ age of 55.6 + 0.17 Ma (Borden and others, 1992). Two conventional K/Ar ages from hydrothermally altered, mineralized dikes farther north on the Kenai Peninsula have have yielded similar results (53.2 ± 1.6 Ma and 52.7 ± 1.6 Ma; Silberman and others, 1981). Accordingly, we suggest that the ore-forming fluids were generated and mobilized during subduction of a spreading center.

Shallow structures formed during subduction of a spreading ridge beneath the Chugach–Prince William accretionary prism are shown schematically in figure 4. At depth, partial melting of accreted sediments above a slab window led to intrusion of granitoids and high-grade metamorphism (as exposed in the eastern Chugach Mountains). At shallower levels, dike injection and movement on conjugate strike-slip faults together resulted in orogen-parallel

extension; some of these structures host lode gold. Owing to migration of the triple junction, the accretionary prism experienced a rapid succession of three very different tectonic regimes—before, during, and after ridge subduction.

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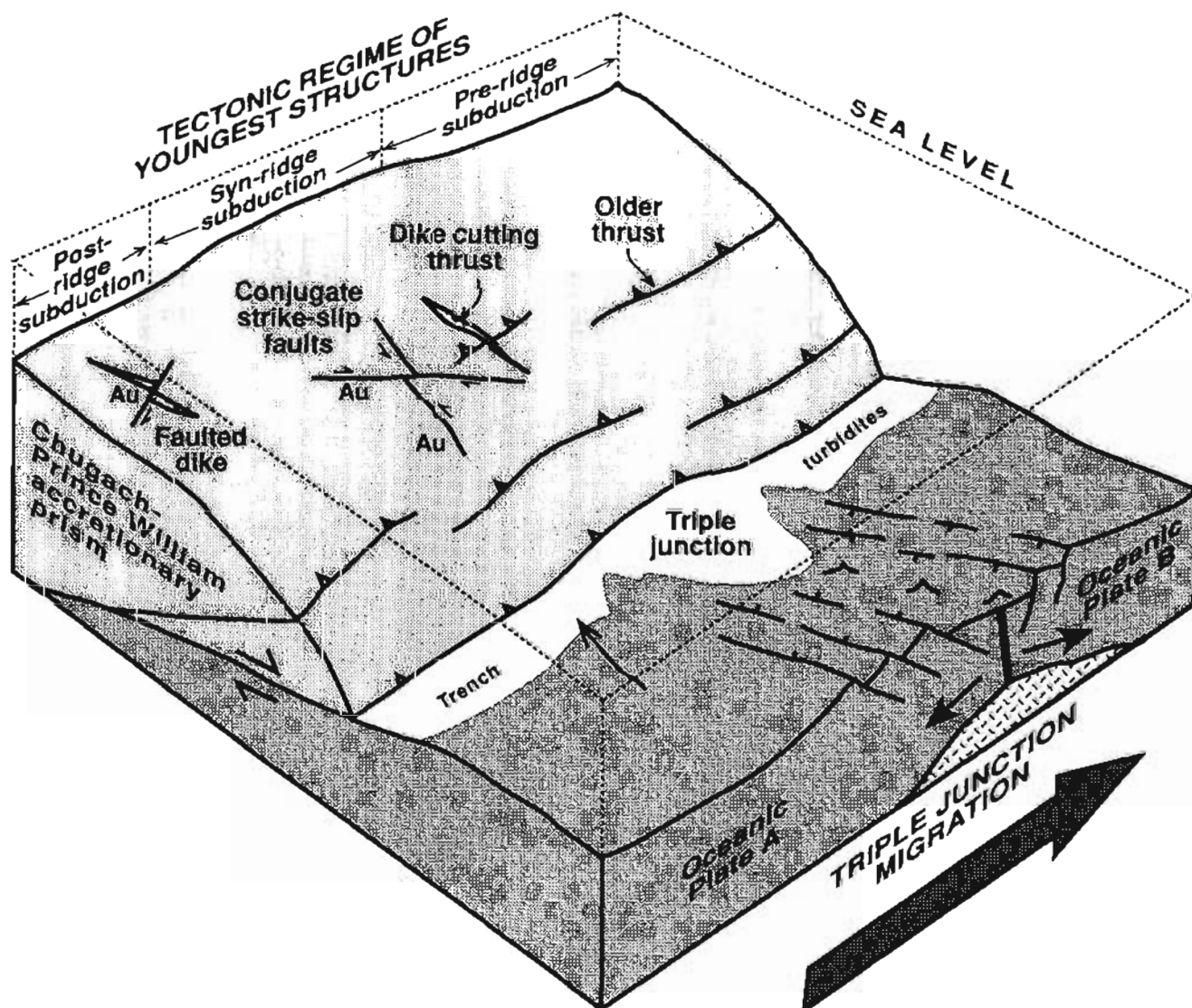
Figure 4. Schematic depiction of conditions during subduction of spreading ridge beneath Chugach–Prince William composite terrane. Oceanic plates A and B correspond, respectively, to Kula and Farallon plates, or to "West Kula" and "East Kula" plates. At depth within accretionary prism, partial melting of accreted rocks above a "slab window" leads to intrusion of granitoids. At shallower levels shown here, dike injection and movement on conjugate strike-slip faults together result in orogen-parallel extension. Left-to-right migration of triple junction (inferred from age progression in fig. 2) subjects accretionary prism to succession of three very different tectonic regimes—before, during, and after ridge subduction. Structures that host lode gold (Au symbol) formed, at least in part, in ridge subduction environment. Adapted, in part, from unpublished figure by Steve Nelson.

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Table 1. Isotopic ages of intrusive rocks from the Sanak-Baranof belt, southern Alaska

[Abbreviations for 1:250,000-scale quadrangles: Afog, Afognak; Anc. Anchorage; BG. Bering Glacier; Bly, Blying Sound; Cor, Cordova; FP, False Pass; Kag, Kaguyak; Kod, Kodiak; MF, Mt. Fairweather; MSE, Mt. St. Elias; PA, Port Alexander; PM, Port Moller; Sel, Seldovia; Sew, Seward; Sim, Simeonof Island; Sit, Sitka; Skag, Skagway; Step, Stepovak Bay; Sut, Sutwik Island; Trin, Trinity Islands; Val, Valdez; Yak, Yakutat. Distance along strike was measured from the southern tip of Sanak Island on Beikman's (1980) geologic map of Alaska. Notes: 1, Not plotted in figure 2B, because error >10%; 2, Not plotted in figure 2B, because strongly discordant with older determination(s) from same pluton; 3, Problematic age from a pluton with multiple determinations; 4, Suspect, but plotted in figure 2B; 5, Recalculated using new decay constant (most recalculated values are from Wilson and others, 1991); 6, Glacial erratic assumed to have been derived from the Kodiak batholith]

Igneous body	Quad	Field number or location	Latitude	Longitude	Age (Ma)	Error (m.y.)	Notes	Method	Distance from Sanak Island (km)	Reference
Sanak pluton	FP	S-70	54°29.2'	162°45.8'	61.4	1.8	5	K/Ar biotite	5	Moore, 1974a
Sanak pluton	FP	S70	54°29.2'	162°45.8'	62.7	1.2		Rb/Sr min. isochron	5	Hill and others, 1981
Sanak pluton	FP	75089	~54°29'	~162° 45'	62	1.9	5	K/Ar biotite	7	Kienle & Turner, 1976
Sanak pluton	FP	S9A	54°29.8'	162°45.1'	63.1	1.2		Rb/Sr min. isochron	7	Hill and others, 1981
Sanak pluton	FP	many	54°28.5'	162°45.0'	49.5	5.6	1,2	Rb/Sr w.r. isochron	7	Hill and others, 1981
Shumagin pluton	Sim	N131	54°52.8'	160°11.7'	58.7	1.2		Rb/Sr min. isochron	180	Hill and others, 1981
Shumagin pluton	PM	N20	55°02.7'	160°05.3'	60.4	2.6		Rb/Sr min. isochron	195	Hill and others, 1981
Shumagin pluton	PM	405M	55°03.2'	160°02.5'	57.4	2.9	5	K/Ar muscovite	195	Burk, 1965
Shumagin pluton	PM	406M	55°06.8'	160°01.7'	65.6	3.3	5	K/Ar muscovite	200	Burk, 1965
Shumagin pluton	PM	406B	55°06.8'	160°01.7'	58.4	2.9	5	K/Ar biotite	200	Burk, 1965
Shumagin pluton	PM	75092	55°05'	160°00'	60.7	1.8	5	K/Ar biotite	200	Kienle & Turner, 1976
Shumagin pluton	Step	many	~55°8'	~159°45'	59.8	3		Rb/Sr w.r. isochron	215	Hill and others, 1981
Shumagin pluton	Step	75088	55°08.9'	159°32.0'	60.2	1.8	5	K/Ar biotite	230	Kienle & Turner, 1976
Shumagin pluton	Sim	62AGz7	54°55.0'	159°14.4'	59.9	3.0	5	K/Ar biotite	235	Moore, 1974b
Chowiet pluton	Sut	75086	56°02.7'	156°41.3'	59.3	1.8	5	K/Ar biotite	435	Kienle & Turner, 1976
Kempf Bay pluton	Trin	62AMe120	56°55'	154°13'	61.9	2.9		K/Ar muscovite	610	Marvin & Dobson, 1979
Kempf Bay pluton	Trin	62AMe120	56°55'	154°13'	60.8	3		K/Ar biotite	610	Marvin & Dobson, 1979
Aliulik pluton	Kag	A2	56°59'	153°44'	63	3		Rb/Sr min. isochron	640	Moore and others 1983
Aliulik pluton	Kag	A2	56°59'	153°44'	62.6	0.6		K/Ar biotite	640	Moore and others 1983
Aliulik pluton	Kag	A2	56°59'	153°44'	62.1	0.6		K/Ar biotite	640	Moore and others 1983
Kodiak batholith	Kod	62AKa10	57°26'	152°58'	59.5		6	K/Ar biotite	700	Moore and others 1983
Kodiak batholith	Kod	Terror Lake	~57°40'	~153°00'	58.3	0.3		40/39(?) biotite	715	W. Clendenin, written comm., 1992
Stock, Anton Larsen Bay	Kod	78AWs1	57°52'	152°40'	58.1	1		K/Ar biotite	750	Wilson and others, 1991
Stock, Anton Larsen Bay	Kod	78AWs1	57°52'	152°40'	57.1	1		K/Ar muscovite	750	Wilson and others, 1991
Dike, Malina Bay	Afog	M-19-88	58°12.6'	153°00.1'	59.3	2.2		40/39 hornblende	765	Clendenin, 1991
Dike, Seldovia Bay	Sel	88ADw230	59°23.6'	150°39.9'	57	0.22		40/39 hornblende	920	Clendenin, in Bradley & Kusky, 1992
Nuka pluton	Sel	88ACy9	59°28.4'	150°20.2'	54.2	0.08		40/39 biotite	970	Clendenin, in Bradley & Kusky, 1992
Nuka pluton	Sel	88ACy9	59°28.4'	150°20.2'	56	0.5		U/Pb monazite	970	Parrish, in Bradley & Kusky, 1992
Aialik pluton	Bly	loc. 5	59°42.4'	149°31.4'	59.2	1.8		K/Ar biotite	1015	Tysdal and Case, 1979
Aialik pluton	Bly	loc. 5	59°42.4'	149°31.4'	54.6	1.6		K/Ar muscovite	1015	Tysdal and Case, 1979
Dike, Oracle Mine	Sew	81BS116C	60°37'	149°34.5'	52.5	1.6		K/Ar whole rock	1100	Nelson and others, 1985
Dike, Kenai Star Mine	Sew	2203N	60°50.7'	149°30.6'	52.7	1.6		K/Ar whole rock	1125	Silberman and others, 1981
Nellie Juan pluton	Sew	PW-9	60°29.5'	148°23.0'	36.1	0.9	5	K/Ar biotite	1125	Lanphere, 1966
Dike, Bear Creek	Sew	2237B	~60°52.7'	~149°31.6'	53.2	1.6		K/Ar muscovite	1130	Silberman and others, 1981
Dike, Potter Marsh	Anc	70ACs423	61°04.0'	149°47.5'	34.8	2.0		K/Ar hornblende	1135	Clark and others, 1976
Eshamy pluton	Sew	PW-8	60°27.0'	148°06.5'	36.2	1.0	5	K/Ar biotite	1140	Lanphere, 1966
Eshamy pluton	Sew	PW-8	60°27.0'	148°06.5'	34.4	1.2	5	K/Ar hornblende	1140	Lanphere, 1966
Crow Pass pluton	Anc	80AMS34	61°3.2'	149°6.1'	54.5	1.6		K/Ar muscovite	1150	Nelson and others, 1985
Crow Pass pluton	Anc	80KMS321	61°3.2'	149°6.1'	54.8	2.7		K/Ar whole rock	1150	Nelson and others, 1985
Sill, Eagle River	Anc	CKA-1	61°16.2'	149°17.1'	50.2	2.5		K/Ar whole rock	1165	Updike and Ulery, 1988
Passage Canal pluton	Sew	PW-1	60°50.0'	148°29.0'	36.6	1.0	5	K/Ar biotite	1165	Lanphere, 1966
Dike, Peters Creek	Anc	CKA-2	61°19.1'	149°18.7'	50	2.6		K/Ar whole rock	1170	Updike and Ulery, 1988

Igneous body	Quad	Field number or location	Latitude	Longitude	Age (Ma)	Error (m.y.)	Notes	Method	Distance from Sanak Island (km)	Reference
Esther pluton	Sew	PW-2	60°50.0'	148°03.0'	35.5	0.9	5	K/Ar biotite	1185	Lanphere, 1966
Perry Island pluton	Sew	80ANs60A	60°44.3'	147°57.5'	34.2	1.7		K/Ar whole rock	1185	Nelson and others, 1985
Sill, Gravel Creek area	Anc	none given	~61°40'	~147°55'	57.2	3.2		K/Ar hornblende	1240	Little and Nueser, 1989
Miners Bay pluton	Anc	81AMH69A	61°05.7'	147°30.2'	32.2	1.6	2	K/Ar biotite	1240	Nelson and others, 1985
Miners Bay pluton	Anc	81ANs82	61°05.7'	147°30.2'	38.4	1.9		K/Ar hornblende	1240	Nelson and others, 1985
Dike, Harvard Glacier	Anc	81AMH65A	61°23.2'	147°32.3'	43.6	1.6		K/Ar whole rock	1245	Nelson and others, 1985
Stock near Mt. Cameron	Val	79PW8	61°12.4'	144°46.5'	51.6	1.5		K/Ar muscovite	1305	Winkler and others, 1981
Sheep Bay pluton	Cor	71APr22	60°42'	146°08'	50.5	1.5		K/Ar hornblende	1345	Winkler and Plafker, 1981
Sheep Bay pluton	Cor	71APr22C	60°42'	146°08'	53.2	1.6		K/Ar biotite	1345	Winkler and Plafker, 1981
Rude River pluton (gabbro)	Cor	85ANk96B	60°41.8'	145°31.1'	64.5	2.1	3	K/Ar hornblende	1380	Plafker, in Wilson and others, 1991
Rude River pluton (granodiorite)	Cor	84APr8	60°42.1'	145°29.2'	49.9	1.5		K/Ar hornblende	1380	Plafker, in Wilson and others, 1991
Rude River pluton (granodiorite)	Cor	84APr8	60°42.1'	145°29.2'	52.3	1.6		K/Ar biotite	1380	Plafker, in Wilson and others, 1991
Dike, Cirque Creek	Val	84APe97	61°19.1'	144°53.2'	52.2	1.6		K/Ar biotite	1390	Plafker and others, 1989
Dike, Cirque Creek	Val	84APe97	61°19.1'	144°53.2'	43.6	3.1	2	K/Ar hornblende	1390	Plafker and others, 1989
McKinley Peak pluton	Cor	84APr9	60°34.4'	145°15.1'	51.4	1.5		K/Ar biotite	1400	Plafker, in Wilson and others, 1991
McKinley Peak pluton	Cor	67APr1	60°28'	145°20'	51.6	2		K/Ar phlogopite	1405	Winkler and Plafker, 1981
Dike, Cordova area	Cor	none given	60°28'	145°20'	44	—		K/Ar whole rock	1405	Barker and others, 1992
Dike, Cordova area	Cor	none given	60°28'	145°20'	47.2	—		K/Ar whole rock	1405	Barker and others, 1992
Dike, Cordova area	Cor	none given	60°28'	145°20'	52	—		K/Ar whole rock	1405	Barker and others, 1992
McKinley Pk pluton	Cor	85APr140	60°32.3'	145°11.2'	47.2	1.4	2	K/Ar whole rock	1405	Plafker, in Wilson and others, 1991
Pluton south of Miles Glacier	Cor	80ANs148A	60°29'	144°23'	52.7	1.6		K/Ar biotite	1425	Winkler and Plafker, 1981
Pluton south of Miles Glacier	Cor	80ANs148A	60°29'	144°23'	51.3	2.9		K/Ar hornblende	1425	Winkler and Plafker, 1981
Pluton, upper Miles Glacier	Cor	71APr20C	60°39'	144°10'	50.9	1.5		K/Ar biotite	1425	Winkler and Plafker, 1981
Pluton , upper Miles Glacier	Cor	71APr25C	60°29'	144°23'	53.5	1.6		K/Ar hornblende	1430	Winkler and Plafker, 1981
Pluton, upper Miles Glacier	Cor	71APr20B	60°36'	144°11'	50.6	1.5		K/Ar hornblende	1430	Winkler and Plafker, 1981
Bremner Glacier pluton	BG	74APr151-H	60°53.5'	143°27'	51.2	2.6		40/39 actinolite	1470	Sisson and others, 1989
Bremner Glacier pluton	BG	74APr151	60°53.5'	143°27'	65.7	7.2	3	K/Ar hornblende	1470	Plafker in Onstott and others (1989)
Bremner Glacier pluton	BG	74APr151	60°53.5'	143°27'	50.1	2.0		K/Ar biotite	1470	Plafker, in Wilson and others, 1991
Tana Glacier sill	BG	84ASn103-H1	60°44.5'	142°43'	52.8	0.8		40/39 hornblende	1520	Sisson and others, 1989
Tana Glacier sill	BG	84ASn103-B2	60°44.5'	142°43'	50.1	0.5		40/39 biotite	1520	Sisson and others, 1989
Tana Glacier sill	BG	84ASn103-P2	60°44.5'	142°43'	35.3	2.2	2	40/39 plagioclase	1520	Sisson and others, 1989
Bremner Glacier pluton	BG	73APr300	60°58.7'	143°21.6'	60.5	3.6	3	K/Ar hornblende	1525	Plafker, in Wilson and others, 1991
Bremner Glacier pluton	BG	73APr300	60°58.7'	143°21.6'	47.2	1.8		K/Ar biotite	1525	Plafker, in Wilson and others, 1991
Bremner Glacier pluton	BG	84APr198	60°56.4'	143°18.7'	49.4	1.5		K/Ar biotite	1530	Plafker, in Wilson and others, 1991
Bremner Glacier pluton	BG	84APr198	60°56.4'	143°18.7'	48.4	1.5		K/Ar hornblende	1530	Plafker, in Wilson and others, 1991
Pluton, upper Miles Glacier	BG	none given	60°43.7'	143°22'	59	—	3	K/Ar hornblende	1530	Onstott and others, 1989 (fig. 1 only)
Pluton, upper Miles Glacier	BG	none given	60°43.7'	143°22'	46	—		K/Ar biotite	1530	Onstott and others, 1989 (fig. 1 only)
Pluton north of Granite Ck.	BG	73AH275B	60°46.3'	142°04.0'	50.2	2.0		K/Ar biotite	1550	Plafker, in Wilson and others, 1991
Pluton south of Granite Ck.	BG	73AH274B	60°42.9'	141°54.5'	49.9	2.0		K/Ar biotite	1560	Plafker, in Wilson and others, 1991
Pluton south of Granite Ck.	BG	84APr197B	60°42.8'	141°54.3'	27.4	0.8	2	K/Ar biotite	1560	Plafker, in Wilson and others, 1991
Jeffries pluton	BG	73AH273A	60°41.5'	141°43.6'	52.6	2.0		K/Ar biotite	1570	Plafker, in Wilson and others, 1991
King Peak pluton	MSE	106CAc771	60°36.25'	140°51.9'	50	2.4		K/Ar biotite	1615	Dodds and Campbell, 1988
Mt. Newton pluton	MSE	69APr48A	60°19'	140°50'	27.4	22.9	1	K/Ar hornblende	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE	69APr54A	60°17'	140°53'	89.3	3.1	5,3	K/Ar biotite	1625	Hudson and others, 1977
Mt. Saint Elias pluton	MSE	69APr54A	60°17'	140°53'	54.2	1.7	5	K/Ar hornblende	1625	Hudson and others, 1977
Mt. Saint Elias pluton	MSE	69APr54A	60°17'	140°53'	56.1	9.5	1	K/Ar hornblende	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE	138CAc771	60°12.9'	140°56.1'	35.8	2.1	2	K/Ar biotite	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE	138CAc771	60°12.9'	140°56.1'	60.5	8.2	1	K/Ar hornblende	1625	Dodds and Campbell, 1988

Table 1. Isotopic ages of intrusive rocks from the Sanak-Baranof belt, southern Alaska—Continued

[Abbreviations for 1:250,000-scale quadrangles: Afog, Afognak; Anc, Anchorage; BG, Bering Glacier; Bly, Blying Sound; Cor, Cordova; FP, False Pass; Kag, Kaguyak; Kod, Kodiak; MF, Mt. Fairweather; MSE, Mt. St. Elias; PA, Port Alexander; PM, Port Moller; Sel, Seldovia; Sew, Seward; Sim, Simeonof Island; Sit, Sitka; Skag, Skagway; Step, Stepovak Bay; Sut, Sutwik Island; Trin, Trinity Islands; Val, Valdez; Yak, Yakutat. Distance along strike was measured from the southern tip of Sanak Island on Beikman's (1980) geologic map of Alaska. Notes: 1, Not plotted in figure 2B, because error >10%; 2, Not plotted in figure 2B, because strongly discordant with older determination(s) from same pluton; 3, Problematic age from a pluton with multiple determinations; 4, Suspect, but plotted in figure 2B; 5, Recalculated using new decay constant (most recalculated values are from Wilson and others, 1991); 6, Glacial erratic assumed to have been derived from the Kodiak batholith]

Igneous body	Quad	Field number or location	Latitude	Longitude	Age (Ma)	Error (m.y.)	Notes	Method	Distance from Sanak Island (km)	Reference
Mt. Saint Elias pluton	MSE	138CAc771	60°12.9'	140°56.1'	63.6	8.7	1	K/Ar hornblende	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE ·	138CAc771	60°12.9'	140°56.1'	34.7	1.1	2	K/Ar biotite	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE	138CAc771	60°12.9'	140°56.1'	55.1	1.8		K/Ar hornblende	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE	31CAc781	60°12.9'	140°56.1'	38.4	2.2	2	K/Ar biotite	1625	Dodds and Campbell, 1988
Mt. Saint Elias pluton	MSE	31CAc781	60°12.9'	140°56.1'	67.2	10.7	1	K/Ar hornblende	1625	Dodds and Campbell, 1988
Pluton, upper Seward Glacier	MSE	72CAc741	60°25.1'	140°15'.8'	45.4	2.4		K/Ar biotite	1655	Dodds and Campbell, 1988
Pluton, upper Seward Glacier	MSE	72CAc741	60°25.1'	140°15'.8'	51.5	3.0		K/Ar hornblende	1655	Dodds and Campbell, 1988
Mt. Vancouver pluton	MSE	69APr32A	60°18.1'	139°36.1'	48.0	1.0	5	K/Ar muscovite	1680	Hudson and others, 1977
Mt. Vancouver pluton	MSE	69APr32A	60°18.1'	139°36.1'	44.6	1.0	5	K/Ar biotite	1680	Hudson and others, 1977
Mt. Foresta pluton	MSE	69APr40A	60°13.3'	139°31'	31.4	1.0	5	K/Ar biotite	1690	Hudson and others, 1977
Valerie Glacier pluton	MSE	67APr78A	60°07.6'	139°28.5'	21.4	3.1	5	K/Ar muscovite	1700	Hudson and others, 1977
Valerie Glacier pluton	MSE	67APr78A	60°07.6'	139°28.5'	18.9	1.0	5	K/Ar hornblende	1700	Hudson and others, 1977
Pluton north of Nunatak Fiord	Yak	67APr57B1	59°52.1'	138°58.8'	24.1	0.7	5	K/Ar muscovite	1730	Hudson and others, 1977
Novatak Glacier pluton	Yak	68APr103B	59°37'	138°31'	62.5	2.0	5,3	K/Ar hornblende	1775	Hudson and others, 1977
Novatak Glacier pluton	Yak	68AMk108	59°31.8'	138°23.5'	26	1.0	5,3	K/Ar biotite	1785	Hudson and others, 1977
Alsek River pluton	Yak	67APr94C	59°25.5'	138°00'	23.1	2.0	5,2	K/Ar biotite	1810	Hudson and others, 1977
Alsek River pluton	Yak	67APr94C	59°25.5'	138°00'	21.2	2.8	2	K/Ar biotite	1810	Dodds and Campbell, 1988
Alsek River pluton	Yak	49CAc781	59°24.8'	138°01.5'	32.8	1.9		K/Ar biotite	1810	Dodds and Campbell, 1988
Pluton south of Alsek River	Skag	78AH70	59°21.3'	137°56.8'	26.6	1.1		K/Ar biotite	1810	Plafker, in Wilson and others, 1991
Konamoxt Glacier pluton	Skag	78AH69A	59°21.5'	137°49.7'	52.7	4.0		K/Ar hornblende	1815	Plafker, in Wilson and others, 1991
Konamoxt Glacier pluton	Skag	78AH69A	59°21.5'	137°49.7'	42.4	1.6	2	K/Ar biotite	1815	Plafker, in Wilson and others, 1991
Konamoxt Glacier pluton	Skag	78AH69B	59°21.5'	137°49.7'	42.3	1.6	2	K/Ar biotite	1815	Plafker, in Wilson and others, 1991
Konamoxt Glacier pluton	Skag	78AH69C	59°21.5'	137°49.7'	42.2	1.6	2	K/Ar biotite	1815	Plafker, in Wilson and others, 1991
Konamoxt Glacier pluton	Skag	114CAc781	59°21.6'	137°38.2'	52.4	1.8		K/Ar biotite	1830	Dodds and Campbell, 1988
Jarl Glacier pluton	Skag	113CAc781	59°09.8'	137°17 8'	41	2.2		K/Ar biotite	1865	Dodds and Campbell, 1988
Pluton near Mt. Quincy Adams	MF	77BJ029A	58°53.5'	137°22.0'	28.1	0.8		K/Ar biotite	1880	D. Brew, written commun., 1993
Pluton near Mt. Forde	Skag	77BJ038A	59°02.4'	137°07.4'	44.4	1.3		K/Ar biotite	1880	D. Brew, written commun., 1993
Pluton near Mt. Forde	Skag	77BJ038A	59°02.4'	137°07.4'	37.5	1.1	2	K/Ar hornblende	1880	D. Brew, written commun., 1993
Pluton, S. side J. Hopkins Inlet	MF	66AFD404	58°52.4'	137°02.9'	40.2	1.2		K/Ar biotite	1890	D. Brew, written commun., 1993
Pluton, head J. Hopkins Inlet	MF	66ABd699	58°50.2'	137°08.0'	30.7	0.9	2	K/Ar biotite	1890	D. Brew, written commun., 1993
Pluton, head J. Hopkins Inlet	MF	66ABd699	58°50.2'	137°08.0'	40.8	1.2		K/Ar hornblende	1890	D. Brew, written commun., 1993
La Perouse intrusion	MF	67A	58°35'	137°15'	41.1	2.2		K/Ar hornblende	1910	Hudson and Plafker, 1981
La Perouse intrusion	MF	67B	58°35'	137°15'	32.5	2.5	2	K/Ar hornblende	1910	Hudson and Plafker, 1981
La Perouse intrusion	MF	67C	58°35'	137°15'	22.8	0.9	2	K/Ar biotite	1910	Hudson and Plafker, 1981
La Perouse intrusion	MF	67D	58°35'	137°15'	19.3	0.7	2	K/Ar biotite	1910	Hudson and Plafker, 1981
La Perouse intrusion	MF	67F	58°35'	137°15'	44.2	3.3		K/Ar hornblende	1910	Hudson and Plafker, 1981
La Perouse intrusion	MF	none given	58°35'	137°10'	28.0	8.0	2,1	40/39 plagioclase	1915	Loney and Himmelberg, 1983
Pluton, west side Brady Glacier	MF	66AFD468	58°37.6'	136°53.5'	32.3	1.0	2	K/Ar biotite	1920	D. Brew, written commun., 1993
Pluton, west side Brady Glacier	MF	66AFD468	58°37.6'	136°53.5'	39.4	1.2		K/Ar muscovite	1920	D. Brew, written commun., 1993
Pluton, west side Taylor Bay	MF	76DB123A	58°20'.3'	136°40.3'	38.2	1.1		K/Ar biotite	1950	D. Brew, written commun., 1993
Pluton, west side Taylor Bay	MF	76CN034A	58°17.9'	136°39.8'	30.5	0.9	2	K/Ar biotite	1955	D. Brew, written commun., 1993

Igneous body	Quad	Field number or location	Latitude	Longitude	Age (Ma)	Error (m.y.)	Notes	Method	Distance from Sanak Island (km)	Reference
Pluton on Yakobi Island	Sit	none given	57°59'	136°27'	34.0	1.0	2	K/Ar biotite	1990	Himmelberg and others, 1987
Pluton on Yakobi Island	Sit	none given	57°59'	136°27'	43.6	0.6		K/Ar biotite	1990	Himmelberg and others, 1987
Pluton on Yakobi Island	Sit	79BJ119A	57°59'	136°27'	34.0	1.0	2	K/Ar biotite	1990	Karl and others, 1988
Pluton on Yakobi Island	Sit	79BJ119A	57°59'	136°27'	39.6	1.2		K/Ar hornblende	1990	Karl and others, 1988
Pluton on Yakobi Island	Sit	79BJ108A	57°55'	136°33'	41.7	1.3		K/Ar biotite	1995	Karl and others, 1988
Kruzof Island pluton	Sit	61ABd713a	57°11.5'	135°49.5'	49.8	1.3	5	K/Ar biotite	2080	Loney and others, 1967
Baranof Lake pluton	Sit	62ABd332	57°11'	134°52.5'	43.6	1.1	5	K/Ar biotite	2120	Loney and others, 1967
Baranof Lake pluton	Sit	62ABd332	57°11'	134°52.5'	45.3	1.2	5	K/Ar muscovite	2120	Loney and others, 1967
Baranof Lake pluton	Sit	LK8203	57°06'	134°54.5'	42.1	0.8	5	K/Ar muscovite	2125	Loney and others, 1967
Baranof Lake pluton	Sit	LK8203	57°06'	134°54.5'	43.1	0.8	5	K/Ar muscovite	2125	Loney and others, 1967
Baranof Lake pluton	Sit	62ALy201	57°01'	135°02.5'	48.3	1.3	5	K/Ar biotite	2125	Loney and others, 1967
Baranof Lake pluton	Sit	LK82110	57°04'	134°47.5'	28.7	1.3	5,2	K/Ar biotite	2130	Loney and others, 1967
Baranof Lake pluton	Sit	62APy252	57°03'	134°51'	39.6	0.9	5	K/Ar biotite	2130	Loney and others, 1967
Crawfish Inlet pluton	PA	none given	~56°50'	~135°15'	50.1	0.1		U/Pb zircon	2130	Brew and others, 1991
Crawfish Inlet pluton	PA	81RR170	56°49.6'	135°11.2'	48.3	—		K/Ar biotite	2140	Reifenstuhl, 1983
Crawfish Inlet pluton	PA	81RR170	56°49.6'	135°11.2'	48.0	—		K/Ar biotite	2140	Reifenstuhl, 1983
Dike, Baranof Island	PA	LK8217	56°55'	134°43.5'	37.0	0.4	5	K/Ar biotite	2145	Loney and others, 1967
Crawfish Inlet pluton	PA	LK8211	56°44'	134°43'	47.9	0.5	5	K/Ar biotite	2145	Loney and others, 1967
Crawfish Inlet pluton	PA	63ABd41	56°46.5'	134°56.5'	45.3	1.1	5	K/Ar biotite	2150	Loney and others, 1967
Crawfish Inlet pluton	PA	LK8214	56°43'	134°57'	45.4	0.4	5	K/Ar biotite	2155	Loney and others, 1967
Crawfish Inlet pluton	PA	LK8215A	56°42'	134°53'	47.8	3.1	5	K/Ar biotite	2160	Loney and others, 1967
Crawfish Inlet pluton	PA	LK8215C	56°42'	134°53'	43.0	0.6	5	K/Ar hornblende	2160	Loney and others, 1967
Gut Bay stock	PA	62APy157	56°44'	134°43'	24.9	1.6	5	K/Ar biotite	2165	Loney and others, 1967
Gut Bay stock	PA	LK8202	56°42.5'	134°44.5'	26.4	0.6	5	K/Ar biotite	2165	Loney and others, 1967
Gut Bay stock	PA	LK8201	56°44'	134°38'	25.5	0.5	5	K/Ar biotite	2170	Loney and others, 1967
Gut Bay stock	PA	LK8201	56°44'	134°38'	31.9	0.5	5	K/Ar hornblende	2170	Loney and others, 1967